REPORT 41

SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canadä

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EVALUATION OF ROW CROP PLANTER MODIFICATIONS FOR CORN PRODUCTION WITHIN CONSERVATION TILLAGE SYSTEMS

FINAL REPORT

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EXECUTIVE SUMMARY

Field experiments were conducted in 1990 and 1991 on a silt loam soil at Elora and a loam soil at Woodstock to evaluate various row crop planter modifications for corn production. The study included a total of six location/years; three where the previous crop was grain corn and three where the previous crop had been winter wheat underseeded to red clover. Experimental treatments examined at each site included conventional tillage (spring moldboard plow and secondary tillage) plus a wide range of coulters and residue clearing devices mounted on the planter so as to prepare a seedbed without any prior tillage.

Soil measurements included surface residue cover, soil macroporosity, bulk density, soil moisture and penetrometer resistance. Corn crop response was determined by measuring emergence rates, early season dry matter production, days to 50% corn flowering and final grain yields.

Results indicated that when winter wheat + red clover was the previous crop residue removal from the row area was accomplished more effectively with devices specifically designed for this task (ie. disc furrowers, spoked wheels, etc.) than when coulters were used independently. Following grain corn, however, fluted coulters alone were efficient in removing residue from the row area.

Soil physical property measurements indicated that in the seedbed (depth: 2.5-7.5 cm) fluted coulters resulted in penetrometer resistances, macroporosities and bulk densities that were generally not different from those obtained by moldboard tillage. The strict use of residue clearing devices resulted in seedbed soil strengths and densities which were greater than those resulting from the use of fluted coulters and in some cases slot tillage.

Differences in planting depth variability were generally not significant, however, the addition of residue clearing devices did tend to result in more uniform seed placement

following wheat + red clover.

Early season corn dry matter accumulation generally resulted in higher values for the conventional tillage system compared to any other zero-tillage treatment. At some sites there was a trend for those zero- tillage systems which employed fluted coulters to result in greater dry matter accumulation than when residue clearing devices were used.

Differences in grain corn yields were only significant in one of the six site/years. Following winter wheat + red clover there appears to be a yield advantage for the use of fluted coulters over strict residue removal. In general, fairly wide ranging changes in planting techniques (ie. hand planting, modified zero tillage, moldboard) did not result in yield differences, perhaps due to generally above average growing conditions. Results, therefore, should be interpreted with some caution.

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Background

Conservation tillage systems which generally leave high amounts of residue on the soil surface are increasingly being adopted by Ontario farmers. Within these systems, significant row-crop yield benefits have often been attributed to removing surface residues from the row area and from loosening the soil in the row area at planting time.

Recently, there has been a great deal of interest generated by the farm press, equipment manufacturers and farmers themselves in the various planter attachments that exist for altering the conditions of the row area while planting. Generally these attachments can be divided into the two principal groups of residue removal and soil loosening devices.

Devices designed specifically for residue removal have included equipment such as disc furrowers, wire brushes, spoked wheels, horizontal blades and V-shaped sweeps. All of these have been employed with varying degrees of success depending on the crop residue to be removed and whether or not some tillage has been done prior to the planting operation. Most residue removal devices face the challenge of effectively removing residue from the row area without coincidental removal of soil from the seedbed surface.

Soil loosening in the row area during the planting operation has been done using coulters, sweeps, disks or PTO powered attachments. Our objective, however, in this study will deal principally with coulters as the soil loosening equipment; employing different types and arrangements on the planter.

The use of the ripple and bubble coulter was principally for opening a narrow slot so that the fertilizer and seed openers could consistently work at the proper depth in the otherwise untilled soil. The fluted coulter with a one or two inch fluted blade loosens a larger volume of soil and also tends to move greater amounts of residue out of the row area. This coulter

action allows the seed and fertilizer to be placed at the correct depth but also prepares a looser seedbed to hopefully enhance early crop growth.

Unfortunately, there has been little objective scientific testing of these modifications in terms of their effect on soil properties and crop growth and in the assessment of their relative merits within a controlled study. This void in information was partially addressed by a study which evaluated planter modifications in terms of their effects on both soil properties and crop growth. Soil property measurements were essential so that our conclusions will not deal merely in terms of grain yield resulting from the use of a specific attachment but include general recommendations relating crop yield to seedbed conditions.

Objective

The objective of this study was to evaluate row crop planter modifications in terms of their effect on seedbed conditions and corn growth and yield in order to assist producers in selecting planter attachments for conservation tillage systems.

MATERIALS AND METHODS

Experimental Background

This study extended over two growing seasons and included a total of six experimental sites. In 1990 two experimental sites were set up on the farm of Mr. Ross Gammie near Elora, Ontario (soil type was a silt loam). Previous crops of grain corn and winter wheat (underseeded to red clover) had been grown in 1989 on these sites. In 1991 two experimental sites were again established on Mr. Gammie's farm; similarly to the previous year one had grain corn residue and the other had winter wheat + red clover. In addition, in 1991 two experimental sites were located in the Woodstock area. One site (previous crop winter wheat

+ red clover) was located on the farm of Mr. Bob Hart while the second (previous crop grain corn) was established on the Woodstock Research Station operated by the University of Guelph.

The Elora sites had traditionally been spring molboard plowed each year when corn was to be grown. The Woodstock sites had usually been fall chisel plowed in years prior to the experimental year.

Cultural Practices

Cultural practices for the experimental sites were generally standard agronomic practices and are detailed in Table 1.

Table 1. Cultural practices for the zero-tillage modification experiments at Elora and Woodstock in 1990 and 1991.

Cultural practise	Elora 1990	Elora 1991	Woodstock 1991
Corn hybrid	P3902	P3902	P3790
Planting population plants ha^{-1}	73,800	73,800	73,800
Starter fertilizer ($kg\ ha^{-1}$)	5-20-20 (190)	11-52-0 (125)	11-52-0 (125)
Nitrogen fertilizer applied as UAN 28%	140 kg Nha^{-1}	140 kg Nha^{-1}	140 kg Nha^{-1}
Herbicides			
Red clover control (2 weeks pre-plant)	2,4-D + Assist ($2.5\ l\ ha^{-1} + 5.0\ l\ ha^{-1}$)		
Perennial weed control	Round-up $5.0\ l\ ha^{-1}$		
Annual weed control	Bladex + Dual ($4.75\ l\ ha^{-1} + 2.75\ l\ ha^{-1}$)		
Insecticide (where previous crop was corn)	Dyfonate ($7.3\ kg\ ha^{-1}$)	Counter ($10\ kg\ ha^{-1}$)	

Experimental Treatments

Over the two years of the study a total of 14 experimental treatments were examined. These treatments, with their respective descriptions, are outlined in Table 2.

Table 2. Description of the experimental treatments used in this study.

Experimental Treatment	Description
1) Moldboard	Spring moldboard plowing (depth 15 cm) followed by field cultivation (2x).
2) Hand planted	Seeds were uniformly inserted by hand 2 cm beside fertilizer band. Only mechanical disturbance was ripple fertilizer coulter.
3) Slot	Single ripple coulter/fertilizer applicator applied fertilizer 2 cm beside, and 4 cm below seed (common to all treatments). Single, 1" bubble coulter was mounted directly in front of double disc openers (common to all treatments except 2, 5, 12 and 13).
4) Disc furrowers (1)	One set of disc furrowers mounted at the front of the planter on a gauge wheel assembly. Adjusted to skim soil surface removing residue from an 8-10 cm wide band.
5) Disc furrowers (2)	Include two sets of disc furrowers, one set mounted as above and the second set was mounted on the parallel arms of the planter unit. The second set had the discs separated by 4 cm in order to remove residue from a 15-18 cm wide band.
6) Wire brushes	2 Polypropelene brushes, arranged in a V formation were mounted on the gauge wheel at the front of the planter.
7) Spoked wheels	2 Spoked wheels, arranged in a V formation were mounted on the gauge wheel assembly at the front of the planter.
8) 2 Fluted coulters (2")	Two, 2" fluted coulters were mounted on front of the planter approximately 12 cm apart. Operating at a depth of 8 cm.
9) 2 Fluted coulters (1")	Two, 1" fluted coulters were mounted on front of the planter approximately 10 cm apart. Operating depth was 12 cm.
10) 3 Fluted coulters	One, 1" and two 2" coulters were mounted on the front of the planter approximately 10 cm apart. Operating depth was 8 cm.
11) Fluted coulters + V	Coulters mounted as in #8 followed by V-shaped sweep.
12) Fluted coulters + brushes	Coulter mounted as in #8 followed by wire brushes mounted on planter unit.
13) Fluted coulters + spokes	Coulters mounted in #8 followed by spoked wheels mounted on the planter unit.
14) Fluted coulters + furrowers	Disc furrowers were mounted on front of planter as in #4 followed by fluted coulters as in #8.

Measurements

Residue Cover

Residue cover was measured using a nylon rope with 50 markings which was placed over the in-row area of each plot. Percent residue coverage was determined from the total number of rope markings which lay directly over previous crop residue. Two determinations were made in each plot.

Soil Moisture

Volumetric soil moisture was determined using the Time Domain Reflectometry (TDR) method (Topp et al., 1984). Stainless steel probes were inserted into the row area to depths of 15 cm and 20 cm in 1990 and 1991 respectively. Two determinations per plot were made in all location/years.

Macroporosity and Bulk Density

Undisturbed soil cores (core size: 4.7 cm x 5.0 cm) were taken following the planting operation in the in-row area in the depth interval of 2.5 - 7.5 cm. These soil cores were taken to the laboratory, trimmed, saturated, weighed and placed on a pressure plate apparatus. These cores were then allowed to equillibrate at 0.33 bar pressure in the pressure plate chamber. Cores were weighed (to determine macroporosity) and then the soil was removed and oven dryed to determine dry bulk density.

Penetrometer Resistance

Penetrometer resistance was determined using a Rimik hand-held recording penetrometer. These measurements were taken in mid-season in 1990 and within three weeks after planting in 1991. Penetrometer insertions were made directly in the row area to depth of 20 cm. A minimum of 5 insertions were made in each plot. Soil moisture measurements were also taken at the time of penetrometer resistance to assure that soil moisture differences were not obscuring treatment effects.

Emergence Rates and Planting Depth Variability

Emergence rates were recorded at the Elora sites by observing the number of days required for 50 % of the plants in 5 m of row to emerge. In 1991, at approximately the sixth leaf stage, 12 plants in each plot were removed carefully fron the soil to determine planting depth. Mean absolute deviations from the average planting depth in each plot were then determined.

Corn Growth, Development and Grain Yields

Dry matter accumulation was determined from whole plant harvests of 12 - 15 plants per plot. Development was assessed by determining the number of days from planting required for 50 % of the plants in a 20 plant section of row to have silks emerge from the ear. Final grain corn yields were determined by hand harvesting 10 m of row from each plot. These cobs were then shelled by a small thresher followed by determinations of grain weight and moisture.

Statistical Design and Analysis

Each experimental site employed a randomized complete block design with four replications. There were a total of 9 treatments in 1990 and 11 in 1991. All plot measurements were analyzed using accepted analysis of variance procedures. Treatments were determined to be different by using a protected Least Significant Differnce (LSD) at the 5% probability level. Within this report, the letters NS indicate a column of treatment means which are not different at the 5% probability level.

RESULTS

Residue Cover

When corn was the previous crop, various planter options caused significant differences in in-row residue coverage at all sites (Table 3). In general, residue removing devices alone tended to result in lower residue levels than fluted coulters alone although these differences

were usually not significant. The combination of coulters and residue removing devices were very effective at removing residue from the row area at both Elora and Woodstock. They resulted in residue levels which were not significantly different than those obtained from moldboard plowing and field cultivation.

The wire brushes and passive "V" sweeps proved to be ineffectual in removing corn residue in 1990 and were precluded from further investigation. These types of devices would no doubt prove more effective at clearing soybean residue or residues which were not anchored (ie. had been chisel or disced previously).

Table 4 outlines in-row residue measurements taken over the course of the study when winter wheat/red clover was the previous crop. In terms of residue clearing devices, disc furrowers resulted in significantly lower in-row residue than either wire brushes or spoked wheels when the previous crop was wheat/red clover. Residue levels following disc furrowers were, in most cases, significantly lower than those resulting from fluted coulters. Combinations of fluted coulters and residue clearing devices were generally lower than coulters alone and similar to residue cleared (alone) results.

In comparing the residue clearing abilities of the various options it appeared that disc furrowers were required to reduce residue to levels significantly below the slot treatment only when wheat/red clover was the preceding crop. When corn was the preceding crop fluted coulters or spoked wheels were also able to cause significant removal of residue from the row area.

Table 3. The effect of planter modification treatments on in-row residue cover after planting. Previous crop was grain corn.

Treatments	Location/year		
	Elora/90	Elora/91	Woodstock/91
	% residue cover		
Moldboard	8	21	14
Hand planted	-	45	59
Slot	36	43	51
Disc furrowers (1)	30	36	32
Disc furrowers (2)	28	12	28
Wire brushes	48	-	-
Spoked wheels	-	23	37
2 Fluted coulters (2")	38	59	28
2 Fluted coulters (1")	-	28	32
3 Fluted coulters	35	45	29
Fluted coulters + V	38	-	-
Fluted coulters + brushes	35	-	-
Fluted coulters + spokes	-	14	22
Fluted coulters + furrowers	-	25	19
LSD (0.05)	15	21	18

Table 4. The effect of planter modification treatments on in-row residue cover after planting. Previous crop was winter wheat/red clover.

Treatments	Location/year		
	Elora/90	Elora/91	Woodstock/91
	— % residue cover —		
Moldboard	5	18	20
Hand planted	-	86	96
Slot	76	78	60
Disc furrowers (1)	17	26	64
Disc furrowers (2)'	34	30	38
Wire brushes	76	-	-
Spoked wheels	-	74	71
2 Fluted coulters (2")	64	58	47
2 Fluted coulters (1")	-	69	59
3 Fluted coulters	53	51	38
Fluted coulters + V	53	-	-
Fluted coulters + brushes	38	-	-
Fluted coulters + spokes	-	37	36
Fluted coulters + furrowers	-	29	23
LSD (0.05)	14	17	16

Soil Moisture

Volumetric soil moisture was determined using the TDR method at all sites. Soil moisture was determined in the upper 15 cm of the in-row area in mid-season of 1990 and differences among treatments were not significant. In 1991, soil moisture was measured over the 0-20 cm depth interval approximately one week after planting. Only in Woodstock, when the previous crop was winter wheat + red clover were there significant differences among treatments (Table 5). At this site, the zero-tillage treatments which employed coulters resulted in significantly lower soil moisture than either slot or residue clearing treatments. Coultered treatments were

not significantly drier than moldboard but did appear to promote in-row drying within the zero-tillage system.

At Elora, the two experimental sites were adjacent in 1991 and Tabel 5 illustrates the higher soil moisture contents obtained following wheat + red clover compared to following grain corn. It is recognized that within this study the wet soil conditions following wheat + red clover in the spring can be a limiting factor in terms of planting timelines and in obtaining favourable results from planter modifications.

Table 5. The effect of planter modifications on volumetric soil moisture content in the depth interval of 0-20 cm.

Treatment	Location/year:	Elora/91*		Woodstock/91	
	Previous crop:	Corn	W. Wheat + red clover	Corn	W.Wheat + red clover
		water content m^3m^{-3}			
Moldboard		.185	.254	.224	.271
Slot		.173	.260	.233	.300
Disc furrowers (2)		.181	.274	.238	.301
Spoked wheels		.174	.259	.234	.299
2 Fluted coulters (2")		.186	.260	.226	.259
2 Fluted coulters (1")		.159	.239	.229	.257
LSD (0.05)		NS	NS	NS	.03

* Sampling dates at Elora and Woodstock were May 22 and May 28, respectively.

Macroporosity and Bulk Density

At Elora in 1990, when corn was the previous crop, the slot tillage system resulted in significantly lower macroporosity than either moldboard or fluted coulter treatments, which were not different from each other (Table 6). Disc furrowers resulted in macroporosity values

which were intermediate to, and not significantly different from, those obtained by slot tillage and moldboard plowing. In 1991, at both Elora and Woodstock, there was a tendency for residue removing devices (disc furrowers and spoked wheels) to result in lower macroporosity levels than all other treatments when corn was the previous crop. These differences, however, were not statistically significant.

When winter wheat/red clover was the preceding crop there were no differences in macroporosity among any of the treatments at Elora in 1990. In 1991, at both Elora and Woodstock disc furrowers resulted in significantly lower macroporosity levels than all other treatments except spoked wheels. The use of spoked wheels as residue removal device for the planter also tended to reduce macroporosity in the seedbed below those obtained by moldboard, slot and coulter treatments but not to the same extent as the disc furrowers.

Trends in soil dry bulk density at 5 cm below the soil surface mirrored those obtained from the macroporosity analysis (Table 7). In general, relative differences between treatment effects on bulk density were less than those of macroporosity. In particular, at Woodstock, following red clover the use of disc furrowers reduced macroporosity by 45% (significant at P=0.05) compared to fluted coulters. In terms of bulk density, disc furrowers caused an increase of 10% over fluted coulters but this difference was not significant.

Interestingly, the slot tillage system, which employed one bubble coulter (in advance of seed disc openers) and one ripple coulter to apply dry fertilizer resulted in bulk densities in immediate proximity to the seeds which were not significantly different than moldboard in five of the six location/years.

Table 6. The effect of planter modification treatments on macroporosity in the seedbed at the 5 cm depth.

Treatments	Location/year		
	Elora/90	Elora/91	Woodstock/91
	—— % macroporosity * ——		
Previous crop: Grain corn			
Moldboard	20.2	21.3	22.9
Slot	14.8	22.9	21.0
Disc furrowers (2)	18.5	17.9	18.8
Spoked wheels	-	19.0	18.0
2 Fluted coulters (2")	20.5	20.9	22.4
2 Fluted coulters (1")	-	22.2	23.3
LSD (0.05)	5.2	NS	NS
Previous crop: Winter wheat/red clover			
Moldboard	21.3	22.0	16.9
Slot	19.7	19.0	16.2
Disc furrowers	20.2	14.9	9.6
Spoked wheels	-	21.3	13.1
2 Fluted coulters (2")	19.4	23.0	17.5
2 Fluted coulters (1")	-	22.1	17.2
LSD (0.05)	NS	3.9	5.4

* Percent macroporosity is defined as that portion of the total soil volume occupied by pores $\geq$ 0.009 mm in diameter.

Table 7. The effect of corn planter modifications on soil dry bulk density at the 5 cm depth.

Treatments	Location/year		
	Elora/90	Elora/91	Woodstock/91
	bulk density g cm^{-3}		
Previous crop: Grain corn			
Moldboard	1.36	1.22	1.20
Slot	1.45	1.16	1.25
Disc furrowers (2)	1.38	1.25	1.29
Spoked wheels	-	1.24	1.31
2 Fluted coulters (2")	1.33	1.21	1.23
2 Fluted coulters (1")	-	1.19	1.24
LSD (0.05)	0.09	NS	NS
Previous crop: Winter wheat/red clover			
Moldboard	1.26	1.20	1.23
Slot	1.27	1.22	1.24
Disc furrowers	1.29	1.31	1.34
Spoked wheels	-	1.19	1.25
2 Fluted coulters (2")	1.30	1.15	1.22
2 Fluted coulters (1")	-	1.16	1.25
LSD (0.05)	NS	0.07	NS

Penetrometer Resistance

Soil strength was measured in the row area at each site using a hand-held penetrometer. Penetrometer resistance values are reported to a depth of 18 cm when corn was the previous crop (Table 8) and when winter wheat/red clover was the previous crop (Table 9).

Following corn, penetrometer resistance was significantly higher for disc furrowers than for other treatments in the 1.5-4.5 cm depth interval at Elora in both 1990 and 1991. This same

trend was noticed at Woodstock in 1991 but differences were not significant. At Elora (1991) the disc furrowers had higher penetrometer resistances down to depths of 9 cm, in addition, operation of the 1" fluted coulter to a depth of approximately 12 cm significantly reduced penetrometer resistance in the 6-13.5 cm depth interval when compared to operating the 2" fluted coulters to a depth of 7.5 cm.

When winter wheat/red clover was the previous crop, disc furrowers resulted in higher penetrometer resistance in 1.5-4.5 cm only in Elora in 1990. Over both depth intervals of 1.5-4.5 cm and 6-9 cm disc furrowers resulted in the highest penetrometer resistance in all 3 location/years, however these differences were not always significant. Following wheat + clover, operating the 1" fluted coulters to a depth of 12 cm did not, at any site, reduce soil strengths below what resulted from fluted coulters being operated to a depth of 8 cm.

Table 8. The effect of corn planter modifications on penetrometer resistance at various depth intervals. Previous crop was grain corn.

Treatment	Depth interval (cm) 1.5-4.5	6-9	10.5-13.5	15-18
	penetrometer resistance (kPa)			
Site: Elora/90				
Moldboard	376	709	876	1059
Slot	350	780	934	1037
Disc furrower (1)	615	840	848	1175
Disc furrower (2)	383	622	658	901
2 Fluted coulters (2")	326	530	611	819
3 Fluted coulters	390	654	822	1161
LSD (0.05)	112	NS	NS	215
Site: Elora/91				
Moldboard	100	197	472	708
Slot	146	269	382	510
Disc furrowers (2)	263	384	483	670
Spoked wheels	158	315	461	711
Fluted coulters (2")	180	338	422	523
Fluted coulters (1")	127	205	309	542
LSD (0.05)	62	84	108	NS
Site: Woodstock/91				
Moldboard	262	484	806	1018
Slot	318	553	742	1101
Disc furrowers (2)	415	729	878	1147
Spoked wheels	343	578	809	1089
Fluted coulters	315	594	780	999
Fluted coulters (1")	264	534	904	1207
LSD (0.05)	NS	NS	NS	NS

Table 9. The effect of corn planter modifications on penetrometer resistance at various depth intervals. Previous crop was winter wheat/red clover.

Treatment	Depth interval (cm) 1.5-4.5	6-9	10.5-13.5	15-18
	penetrometer resistance (kPa)			
Site: Elora/90				
Moldboard	392	613	645	855
Slot	392	555	607	636
Disc furrower (1)	473	667	663	796
Disc furrower (2)	451	624	687	724
2 Fluted coulters (2")	379	591	695	671
3 Fluted coulters	384	557	642	687
LSD (0.05)	62	NS	NS	NS
Site: Elora/91				
Moldboard	148	226	577	792
Slot	179	228	409	655
Disc furrower (2)	195	351	474	668
Spoked wheels	139	265	385	665
Fluted coulters	161	245	400	582
Fluted coulters (1")	183	301	472	636
LSD (0.05)	NS	85	NS	NS
Site: Woodstock/91				
Moldboard	239	279	414	872
Slot	263	441	768	971
Disc furrowers (2)	452	676	915	1147
Spoked wheels	305	543	765	1074
Fluted coulters	245	462	869	1129
Fluted coulters (1")	259	395	680	898
LSD (0.05)	NS	176	224	NS

Emergence Rates and Planting Depth Variability

Corn emergence rates were significantly altered by the experimental treatments employed at Elora in both 1990 and 1991 (not measured at Woodstock). The tendency in all of these location/years was for moldboard tillage to result in corn emergence significantly earlier than almost all of the other treatments (Table 10). Treatments which employed the residue clearing devices of disc furrowers or spoked wheels either alone or in combination with 2 coulters tended to result in more rapid emergence rates than when fluted coulters were used alone or with wire brushes or V sweeps. Any differences in the observed days to 50% emergence did not appear to be a result of differences in planting depth. Table 11 indicates that at Elora in 1991 when corn was the previous crop there were no significant differences in planting depth among treatments. Although there were significant differences in planting depth among treatments following wheat + red clover there was no pattern relating emergence to planting depth.

One of the aims of this research was to examine the effect of seedbed disturbance by the planter modifications on planting depth variability. Following grain corn, there were no significant differences in planting depth variability regardless of the planter modifications used (data not shown). Following winter wheat + red clover there was a tendancy for the residue clearing devices to reduce planting depth variability at both Elora and Woodstock in 1991 (Table 12). At both sites moldboard plowing resulted in the most uniform planting depth while slot and coulters alone tended to be least uniform.

Table 10. The effect of planter modifications on corn plant emergence rates.

Treatments	Previous Crop: Location/year:	Corn Elora/90	Corn Elora/91	W. Wheat/red clover Elora/90	W. Wheat/red clover Elora/91
		days to 50% emergence			
Moldboard		12.3	8.1	9	8.0
Hand planted		-	9.1	-	9.4
Slot		14.6	9.5	12.5	9.1
Disc furrowers (1)		12.6	9.1	10.8	8.6
Disc furrowers (2)		13.4	9.1	11.8	8.9
Wire brushes		14.4	-	12.4	-
Spoked wheels		-	9.3	-	9.1
2 Fluted coulters (2")		13.5	10.0	10.9	9.5
2 Fluted coulters (1")		-	9.4	-	9.4
3 Fluted coulters		13.1	9.9	11.0	9.5
Fluted coulters + V		13.9	-	12.1	-
Fluted coulters + brushes		13.3	-	11.4	-
Fluted coulters + spokes		-	9.0	-	8.5
Fluted coulters + furrowers		-	8.4	-	9.0
LSD (0.05)		1.01	0.84	0.82	0.56

Table 11. The effect of planter modifications on planting depth at Elora in 1991.

Treatments	Previous crop: Corn	Previous crop: W. Wheat/red clover
	Planting depth (cm)	
Moldboard	5.46	5.69
Hand planted	5.25	5.14
Slot	5.17	5.71
Disc furrowers	5.82	5.91
Disc furrowers	5.77	5.70
Spoked wheels	6.03	5.58
2 Fluted coulters (2")	5.06	5.35
2 Fluted coulters (1")	5.81	4.69
3 Fluted coulters	5.15	5.54
Fluted coulters + spokes	5.78	5.11
Fluted coulters + furrowers	4.95	5.42
LSD (0.05)	NS	.58

Table 12. The effect of planter modifications on corn planting depth variability following winter wheat + red clover in 1991.

Treatment	Location	
	Elora	Woodstock
	mean absolute deviation (mm)*	
Moldboard	5.0	5.8
Slot	8.2	9.0
Disc furrowers (1)	5.2	5.9
Disc furrowers (2)	5.7	5.8
Spoked wheels	5.4	5.8
2 Fluted coulters (2")	5.4	7.5
2 Fluted coulters (1")	9.2	6.0
3 Fluted coulters	6.4	6.2
Fluted coulters + spokes	5.6	6.4
Fluted coulters + furrowers	6.0	5.1
LSD (0.05)	2.3	NS

* Planting depth variability was determined by calculating the mean absolute deviation from the average planting depth of 12 consecutive plants per plot.

Corn Growth and Development

In each year a corn dry matter harvest was conducted in June to examine the planter modification effects on early corn growth. When corn followed corn there were no significant differences in early dry matter accumulation at Elora in 1990 (Table 13). In 1991, at Elora, conventional moldboard tillage resulted in significantly greater dry matter accumulation than all of the zero-tillage options except for 2 fluted coulters + disc furrowers. At Woodstock, in 1991 following corn, moldboard tillage resulted in significantly greater early dry matter accumulation than hand planted, slot, disc furrowers (1+2 sets) and spoked wheels while it was not significantly greater than any of those zero-tillage systems which employed fluted coulters.

When winter wheat + red clover was the previous crop significant early growth differences

existed at all locations. In fact, in each location/year early dry matter accumulation resulting from moldboard tillage was significantly greater than all other zero-tillage options (Table 14). At Elora, in both 1990 and 1991 there were no significant differences in corn dry matter among any of the zero-tillage modifications, however, at Woodstock in 1991 there was a trend similar to that noticed following grain corn, which was that treatments which employed fluted coulters tended to result in greater dry matter accumulation than those which involved minimal disturbance (hand planted, slot) or strict residue removal (disc furrowers (1), disc furrowers (2) and spoked wheels).

Corn development was measured at the Elora sites by recording the number of days from planting to 50% silk emergence. There were significant differences among treatments in both years following both previous crops (Table 15). The principal trend across all sites was for moldboard to result in earlier corn flowering. Among the zero-tillage modifications there did not appear to be any treatments which consistently resulted in more rapid plant development.

Table 13. The effect of planter modifications on early corn dry matter accumulation. Previous crop was corn.

Treatments	Location/year		
	Elora/90*	Elora/91	Woodstock/91
	(mg plant^{-1})		
Moldboard	390	860	2410
Hand planted	-	630	1620
Slot	290	540	1580
Disc furrowers (1)	290	630	1440
Disc furrowers (2)	300	630	1690
Wire brushes	230	-	-
Spoked wheels	-	590	1530
2 Fluted coulters (2")	240	543	2010
2 Fluted coulters (1")	-	640	1790
3 Fluted coulters	280	560	2090
Fluted coulters + V	320	-	-
Fluted coulters + brushes	310	-	-
Fluted coulters + spokes	-	560	1930
Fluted coulters + furrowers	-	743	1850
LSD (0.05)	NS	190	680

* Harvest dates for Elora/90, Elora/91 and Woodstock/91 were June 22, June 6 and June 4, respectively.

Table 14. The effect of planter modifications on early corn dry matter accumulation. Previous crop was winter wheat/red clover.

Treatments	Location/year		
	Elora/90*	Elora/91	Woodstock/91
	(mg plant^{-1})		
Moldboard	230	550	2920
Hand planted	-	410	1680
Slot	150	350	1480
Disc furrowers (1)	140	360	1470
Disc furrowers (2)	120	390	1310
Wire brushes	120	-	-
Spoked wheels	-	390	1470
2 Fluted coulters (2")	160	380	1810
2 Fluted coulters (1")	-	360	1850
3 Fluted coulters	160	350	2010
Fluted coulters + V	150	-	-
Fluted coulters + brushes	140	-	-
Fluted coulters + spokes	-	400	1940
Fluted coulters + furrowers	-	300	1830
LSD (0.05)	34	115	474

* Actual harvest dates for Elora/90, Elora 91 and Woodstock/91 were June 8, June 6, and June 5, respectively.

Table 15. The effect of planter modifications on time to corn silking at Elora.

Treatment	Previous Crop: Year:	Corn 1990	Corn 1991	Winter wheat + red clover* 1991
		days from planting to 50% silk emergence		
Moldboard		69.8	61.8	62.4
Hand planted		-	63.1	65.0
Slot		70.5	63.4	64.4
Disc furrowers (1)		71.3	62.4	66.0
Disc furrowers (2)		70.0	63.1	66.0
Spoked wheels		-	63.4	65.5
2 Fluted coulters (2")		73	64.0	65.9
2 Fluted coulters (1")		-	63.0	64.5
3 Fluted coulters		70.3	62.8	64.9
Fluted coulter + spokes		-	63.6	64.0
Fluted coulter + furrowers		-	62.1	66.9
LSD (0.05)		2.0	1.2	1.6

* 1990 data for corn following wheat + red clover was not recorded.

Final Grain Corn Yields

At both Elora and Woodstock in 1990 and 1991 there were no significant differences in final grain corn yield among any of the tillage treatments when corn was the previous crop (Table 16). Within the zero-tillage treatments there was no apparent advantage to employing any particular type of planter modification.

Following winter wheat + red clover, the moldboard plowed treatment significantly outyielded all treatments except for 2 fluted coulters at Elora in 1990 (Table 17). In 1991 there were no significant differences in final corn yield among any of the treatments at either Elora or Woodstock. However, following winter wheat + red clover there appeared to be a trend

for higher corn yields following treatments which employed coulters compared to residue removal alone. As noted earlier this trend was apparent to a greater degree in early corn dry matter measurements.

Interestingly, in six location years, only once was there a significant grain yield advantage for any planter modifications compared to the simple slot design. In addition, the results did not indicate any differences in final grain yields (following either crop) when seedbeds were treated extremely different (i.e. hand planted vs fluted coulters + spoked wheels).

Table 16. The effect of planter modifications on final grain corn yields. Previous crop was grain corn.

	Location/year		
Treatments	Elora/90	Elora/91	Woodstock/91
	Mg ha^{-1} (15.5% moisture)		
Moldboard	6.55	11.32	10.55
Hand planted	-	12.16	9.70
Slot	6.52	10.88	9.66
Disc furrowers	6.21	11.54	10.11
Disc furrowers	6.51	11.65	10.18
Wire brushes	6.31	-	-
Spoked wheels	-	11.42	9.84
2 Fluted coulters (2")	6.91	10.68	10.02
2 Fluted coulters (1")	-	11.59	10.26
3 Fluted coulters	6.58	11.59	10.00
Fluted coulters + V	6.35	-	-
Fluted coulters + brushes	6.66	-	-
Fluted coulters + spokes	-	11.62	9.96
Fluted coulters + furrowers	-	11.06	9.42
LSD (0.05)	NS	NS	NS

Table 17. The effect of planter modifications on final grain corn yields. Previous crop was winter wheat/red clover.

Treatments	Location/year		
	Elora/90	Elora/91	Woodstock/91
	—— Mg ha^{-1} (15.5% moisture) ——		
Moldboard	7.99	11.52	11.66
Hand planted	-	11.27	10.12
Slot	6.63	11.54	11.07
Disc furrowers	6.77	10.85	10.45
Disc furrowers	6.66	10.63	10.73
Wire brushes	6.90	-	-
Spoked wheels	-	11.0	11.16
2 Fluted coulters (2")	7.44	11.14	11.34
2 Fluted coulters (1")	-	11.31	10.79
3 Fluted coulters	6.95	11.47	10.53
Fluted coulters + V	6.58	-	-
Fluted coulters + brushes	7.03	-	-
Fluted coulters + spokes	-	11.12	11.70
Fluted coulters + furrowers	-	10.46	10.2
LSD (0.05)	.72	NS	NS

DISCUSSION AND CONCLUSIONS

Results from this study indicate that when grain corn has been grown in the previous year fluted coulters are effective in both loosening soil and removing corn residue from the in-row area. However, when winter wheat + red clover is the previous crop, devices such as disc furrowers or spoked wheels are required to provide significant clearing of the in-row area. As producers consider modifications to their row crop planters they need to take crop rotation into consideration. Those rotations which include cereals and/or cover crops may require residue clearing devices if planting in a relatively residue free seedbed is the goal. However, as noted in the results section, there was no advantage outside of slightly earlier corn emergence for

planting corn with strict residue removal.

Corn emergence, early growth and development proved to be consistently superior under the moldboard system compared to any of the zero-tillage options. However, only in one of the six location/years did these differences result in significantly higher corn yields. Within the zero-tillage systems corn emergence tended to be faster for the residue removal treatments. This was not caused by shallower seed placement. The results from our planting depth variability measurements tend to indicate that following wheat + red clover, greater uniformity of planting depth may contribute to enhanced emergence rates when residue clearing devices are used. More rapid soil warming may also accelerate emergence under the residue cleared treatments but this parameter was not measured within this study. In a previous study at Elora removing the in-row residue within a zero tillage system showed consistent grain corn yield advantage over slot tillage when the previous crop was barley underseeded to red clover (Janovicek et al., submitted). These authors indicated that, following barley + red clover, seedbed temperatures were higher when residues were removed from the row area compared to slot tillage.

Negative aspects of the various planter modifications were illustrated by the tendency for seedbeds to have higher bulk density, lower macroporosity and higher penetrometer resistance when residue clearing devices were employed (especially disc furrowers) compared to other treatments. In the case of winter wheat + red clover these soil conditions appeared to have been reflected in corn productivity. That is, strict clearing of the wheat and clover residue tended to lower final grain yields compared to those obtained with the use of fluted coulters. Part of the problem with the disc furrowers modifications when operating in cereal/cover crop type residues is related to wet soil conditions. As noted in the results, soil moistures tended to be higher under wheat + clover residues than under corn residue.

Aggressive movement of residue with disc furrowers may be smearing the soil to some extent and resulting in seedbeds which in terms of soil strength and density are inferior to those of even the slot tillage system.

In fact, the slot tillage system in 1991 compared very favourably to all treatments including moldboard tillage. These results are contrary to our long term tillage study which shows that on a similar soil type slot tillage results in a 10-15% corn yield reduction compared to moldboard tillage when corn follows corn (Vyn and Raimbault, submitted). In light of these results it should be noted that growing conditions at Elora and Woodstock throughout 1991 were very favourable to corn growth. Adequate rainfall and above normal corn heat unit accumulation in May and June may have eliminated environmental stresses which would have negatively affected some treatments more than others.

This study has pointed to some of the benefits and disadvantages of various row crop planter modifications for planting corn following two different previous crops. Recommendations based on corn yield data from this study would not indicate any specific modification or equipment as being consistently superior. Altough some soil loosening appears to be beneficial the modifications which will accomplish this can be simple in design and few in number. Continuing this type of research on a wider variety of soil types and over years with varying climatic conditions will contribute to the promotion of conservation tillage within Ontario agriculture and assist farmers in making informed, objective decisions regarding reduced tillage equipment.

EXTENSION ACTIVITIES

Results from this study have made up all or part of the following presentations which have been given since the beginning of the study or are scheduled for the future.

Residue Removal Attachments for Zero-till Planters. American Society of Agronomy Annual Meetings. October, 1990. San Antonio, Texas.

Plot Tour for Producers. Organized by Grand River Conservation Authority. July, 1991.Elora, Ontario.

Planter Attachments for No-Till. Elora Research Station Field Day. July, 1991. Elora, Ontario.

Corn Response to Red Clover Cover Crop, Tillage Methods and Planter Options. American Society of Agronomy Annual Meetings. October, 1991. Denver, Colorado.

Zero Tillage Corn Production Following Red Clover. OMAF Plant Industry Branch Cover Crop Information Day. November, 1991. Milton, Ontario.

Zero Tillage Practices. W.G. Thompson Producer Information Day. January, 1992. Bethany, Ontario.

Planter Modifications For Zero Tillage. Bluewater Conservation Club Information Meeting. February, 1992. Petrolia, Ontario.

Tillage and Fertility in Ontario. Ontario Corn Producers Annual Meeting. February, 1992. London, Ontario.

Zero Tillage: Impact of Previous Crop and Planter Modifications. Cargill Grain Co. Producer Day. February, 1992. Newmarket, Ontario.

Row Crop Planter Modification for Zero Tillage Corn Production. Innovative Farmers No-Till Workshop. March 3 and 4, 1992. London, Ontario.

Reduced Tillage for Corn and Soybeans. Ball Farm Services Information Day. April, 1992. Aylmer, Ontario.

Reduced Tillage for Corn and Soybeans. Bluewater Conservation Club Information Meeting. April, 1992. Petrolia, Ontario.

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